Predation of the Mediterranean Fruit Fly and the Oriental Fruit Fly (Diptera: Tephritidae) by the Fire Ant (Hymenoptera: Formicidae) in Hawaii

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ABSTRACT

Predation by *Solenopsis geminata* (F.) on mature larvae and teneral adult flies of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) and the oriental fruit fly, *Dacus dorsalis* Hendel, was studied in the laboratory and on the ground beneath guava trees in Hawaii. In the laboratory, *S. geminata* produced 100% larval mortality in *C. capitata* in 15-sec. attacks by an average of 5 ants per larva and 80% larval mortality in *D. dorsalis* in 15-sec. attacks by an average of 4.5 ants per larva. When *C. capitata* and *D. dorsalis* pupae were buried in the soil beneath guava trees in protected cages to permit only ant-sized predators to enter, the average mortality of teneral adult flies from predators was 31.0% and 35.0%, respectively. Total mortality from the time 8-day-old pupae were placed in the field was 73.4% and 70%, respectively, for *C. capitata* and *D. dorsalis*. We infer that predacious ants play a prominent role in this mortality.

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) and the oriental fruit fly, *Dacus dorsalis* Hendel, have been established in the Hawaiian Islands since 1910 (Back & Pemberton 1918) and 1946 (Newell & Haramoto 1968), respectively. Immediate attention focused on a search for natural enemies of these fruit flies. Very little information is available on the role of arthropod predators in controlling population levels in the field. Pemberton & Willard (1918) reported on ants destroying large numbers of tephritid fruit fly larvae, but more data are needed to provide comprehensive ecological information on the relationships between fruit flies and their natural enemies.

This paper is a report on detailed laboratory and field studies of the fire ant, *Solenopsis geminata* (F.) attacking *C. capitata* and *D. dorsalis*. The fire ant is one of the most prevalent ant species found in the Hawaiian Islands (Huddleston & Fluker 1968).

MATERIALS AND METHODS

Laboratory Studies. Field collected colonies of *S. geminata* were maintained in the laboratory as described by Chang & Ota (1976) in

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artificial ant nests either in the Wilson cell (Wilson 1962) or the Bishop nest (Bishop et al. 1980). The nest was placed inside plastic pans (54 by 41 by 13 cm). The interior walls of the pans were coated with Fluon AD-1 liquid (Northeast Chemical, Woonsocket, R.I.) to prevent ants from escaping. Water was provided outside the nest with a bird feeder. Honey water (50%) and artificial ant diet (Banks et al. 1981) were given twice weekly. Ants were reared between 26 and 27°C, 60% RH, and with 8 h light (0700 to 1500h). For two days before each test, ants were allowed to feed to ad libitum.

Predation tests were conducted in a fashion similar to that described by Wong et al. (1984). In each test, 10 popping *C. capitata* or *D. dorsalis* larvae (mature larvae that were able to pupate within 1 hr.) were placed singly in the ant colony. The time period of attack and the maximum number of ants attacking each larva were recorded. At the end of the attack period the larva was dropped into a cup of tap water so that the ants would release their prey. After the ants were removed, each larva was placed in a 5-dram (ca. 19 g) clear plastic vial with moist tissue paper fitted with a snap-on lid and allowed to pupate. Each vial was examined twice daily during the next 14 days and the fate of the larva was recorded. The attack periods by *S. geminata* were 5, 10, 15 and 20 sec. A control consisted of another 10 larvae not exposed to attack but dropped into tap water. The test was conducted 10 times, each time on a separate day with a new group of 10 larvae per treatment, for a total of 100 larvae per treatment. Ten nonflying teneral adults of either *C. capitata* or *D. dorsalis* ca. 2 to 5 min. old were placed individually into the pan containing the ant colony. The number of ants and the time required to kill each teneral adult fly were recorded. The test was repeated five times, each on a separate day.

Field Studies. Field tests were conducted in a guava orchard at the University of Hawaii Experimental Station in Waimanalo, Oahu, Hawaii. During the field tests (31 May to 19 August 1985), the mean daily temperature maxima ranged from 26.7 to 30.0°C and averaged 28.7°C; mean daily temperature minima ranged from 19.4 to 24.4°C and averaged 23.0°C. Monthly rainfall ranged from 0.00 cm during the month of June to 0.35 cm in July and averaged 0.06 cm. Weather data were obtained from a field hygrothermograph located ca. 300 m from the test site.

Ten guava trees, *Psidium guajava* L., were selected for the study. *C. capitata* and *D. dorsalis* pupae were buried in separate containers beneath the guava trees to study the predation of emerging adults by ants. Groups of ten 8-day-old pupae (2 days before emergence) placed in plastic containers (20.32 cm high and 20.3 cm in diam.) were buried ca. 3.8 to 5.1 cm deep in a sand-vermiculite mixture. The plastic container had 2 openings (22.86 cm long and 5.08 cm high) cut 5 cm from the bottom. These openings were covered with a 1 mm mesh aluminum window screening. The bottom of the bucket was forced 4 to 5 cm into the soil allowing the screening to remain above the ground. The 1 mm screen mesh was large enough to allow free access of ants to fly pupae or teneral adults. The

upper half of the inner surface of the container was coated with Bird Stop (Animal Repellants, Griffin, GA.) so that eclosing flies escaping predation could be caught and counted. The container was covered with a tightly fitting screened lid to allow ventilation.

Thus, under each guava tree were 2 containers: one containing *D. dorsalis* pupae, the other *C. capitata* pupae. Each container contained 10 pupae for a total of 100 pupae per species per testing date. The test was repeated 8 times, each time at a different site around the tree. Containers were removed 1 week later; adult flies caught on the sticky substance were counted and the sand was sifted for pupae. Unemerged pupae and empty pupal cases were counted. Mortality of emerging adults was determined by subtracting the number of adults on the sticky substance from the number of empty pupal cases. A set of control pupae was held in the laboratory for comparison with the pupae buried in the field. Relative abundance of ants was estimated by counting the number of ants found in a 1-min. period within a frame (25 by 25 cm) placed randomly on the ground around each of the 10 trees at the time of the start of each test. The data were analyzed using Student's t tests or statistical correlations for comparisons of means or principal factor values, respectively.

RESULTS

Laboratory Studies. The percent mortality of *C. capitata* and *D. dorsalis* larvae attacked by different numbers of ants was calculated for the five time periods of exposure (Figs. 1 and 2). In the controls, 97 to 98% of the larvae successfully became adults, but high larval mortality of both species occurred when attacked by ants. *S. geminata* inflicted 93% ± 0.37(mean ± SE) mortality of *C. capitata* in 5-sec. attacks by an average of 2.2 ± 0.33 ants per larva and 100% mortality in 15-sec. attacks by an average of 5.1 ± 0.18 SE ants per *C. capitata* larva (Fig. 1). No signs of life were observed in larvae within 30 sec. after the 15-sec. attack by 5 *S. geminata*. These ants were presumably able to inject their venom into the larva within seconds of the attack, paralyzing the larva and then killing it quickly with their bites. However, mortality of *D. dorsalis* attacked by *S. geminata* was less severe than for *C. ceratitis*: 51% ± 0.65 SE mortality in 5-sec. attacks by an average of 1.5 ± 0.11 ants per larva and 80% ± 0.63 in 15-sec. attacks by an average of 4.5 ± 0.20 SE ants per larva. The lower mortality caused by *S. geminata* to *D. dorsalis* than *C. capitata* may be due to the differences in the size of these two flies (body weight of *D. dorsalis* is 25-50% greater than that of *C. capitata*).

Of the 50 teneral adults of both fly species placed in the ant colony, all were killed. *S. geminata* immobilized flies quickly (less than 30 sec. after the first ant came into contact) because of their ability to sting.

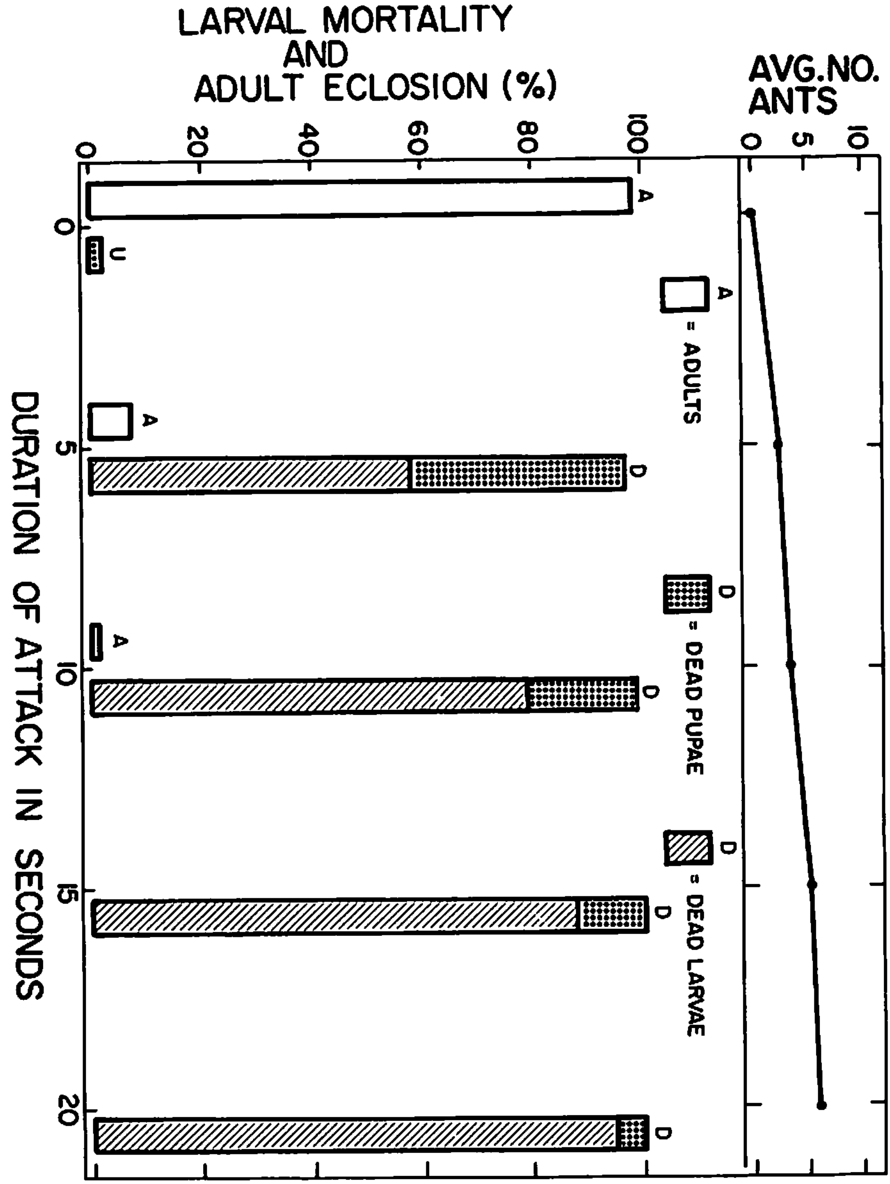

FIGURE 1. Mortality of *C. capitata* attacked by different numbers by *S. germinata* per larvae within four time periods of exposure.

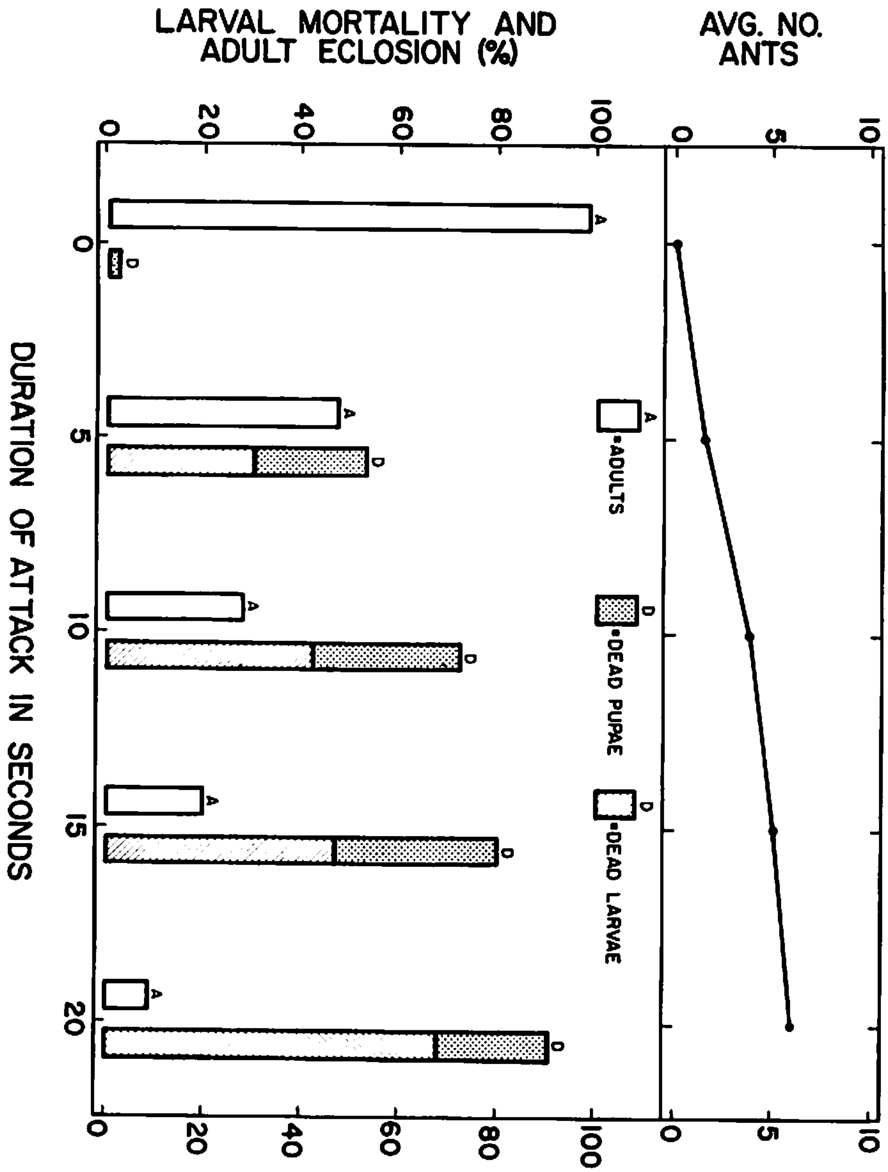

FIGURE 2. Mortality of *D. dorsalis* attacked by different numbers of *S. germinata* per larva within four time periods of exposure.

TABLE 1. Summary of ant predation of *Ceratitis capitata* and *Dacus dorsalis* pupae buried in the soil under 10 guava trees from 31 May 1985 to 19 August 1985 (Waimanalo, Hawaii)

Fly species	No. pupae/ test	No. emerged ($\bar{x} \pm$ SE)	No. flies escaping attack ($\bar{x} \pm$ SE)	No. flies missing or fragments ($\bar{x} \pm$ SE)	% eclosed flies killed by ants ($\bar{x} \pm$ SE)	Other mortality ($\bar{x} \pm$ SE)
C. capitata	100	57.6 ± 8.90	26.6 ± 5.25	31.0 ± 5.10	54.0 ± 5.10	42.4 ± 8.90
D. dorsalis	100	65.0 ± 7.01	30.0 ± 5.70	35.0 ± 2.27	54.0 ± 2.27	35.0 ± 7.01

Control: % adults eclosed from 100 pupae lots
C. capitata 97.0 ± 0.63
D. dorsalis 96.0 ± 2.15

No. ants per 625 cm^2
Total over 8 tests: 429
$\bar{x} \pm$ SE: 53.6 ± 8.53

Field Studies. Table 1 shows the results of *C. capitata* and *D. dorsalis* pupae buried beneath guava trees in Waimanalo, Oahu, Hawaii. The number of ants counted per 10-tree sample over the test period ranged from 26 to 92. The percentage of adults that emerged in the field was significantly lower than for the control samples held in the laboratory (*C. capitata*: $t = 4.45$; d.f. = 14; $P<0.01$; *D. dorsalis*: $t = 4.16$; d.f. = 14; $P<0.01$).

Mortality of adult *C. capitata* and *D. dorsalis* due to ant predation ranged between 17-59% and 26-46%, respectively, with most of the values clustering around the respective means of 31.0 and 35.0%. Significant correlation was observed between the number of ants per sampling date and the observed percentage of combined adult mortality including both *C. capitata* and *D. dorsalis* ($r = .499$, d.f. = 14, $P<0.05$).

DISCUSSION

Huddleston & Fluker (1968) reported that *S. geminata* is found in drier areas of the Hawaiian Islands where it has replaced the dominant big-headed ant, *Pheidole megacephala* (F.). *S. geminata* is most prevalent in habitats ranging from sea level to 304.8 m elevation where rainfall is $\leq$ 50.8 cm. This species tends honey-dew producing insects and preys on small arthropods.

Pimentel (1955) reported that *S. geminata* were seen attacking and killing fully-grown larvae and adult flies of *Musca domestica* L., *Phaenicia* spp., *Callitroga macellaria* (F.), and *Sarcophaga* spp. in Puerto Rico. Whenever *S. geminata* stung a *M. domestica* larva, a black spot ca. 1 mm in diam. developed. As few as two stings paralyzed a larva. The twice-stung larva still pupated and concave areas appeared on the puparium. All larvae stung six or more times died. These results were similar to our laboratory results except that the attack of *S. geminata* to *C. capitata* and *D. dorsalis* seemed more severe than to *M. domestica*.

The 31% and 35% field mortality of *C. capitata* and *D. dorsalis* teneral adults, respectively, were probably higher than under natural conditions because the enclosed cylinders may have hindered the young flies from escaping. We found no direct evidence that predation by ants reduced the number of teneral flies. However, numerous ants along with adult *C. capitata* and *D. dorsalis* were caught by the sticky substance on the inside walls of the cylinders. Fly wings, similar to the wings left behind in laboratory cages after attacks by ants, were found on top of the caged soil. The screen mesh of the plastic containers was small enough to exclude most predators with the exception of ants. Only *S. geminata* was visually observed entering and exiting the containers. However, there is always a small possibility that other predators could have entered the containers but did not become stuck on tbe Bird Stop. Since the only predators caught on the sticky substance were *S. geminata*, we infer that ants were responsible for the clipped fly wings and body parts left in the containers.

Bateman (1976) reported that predation of *D. dorsalis* pupae in Hawaii was almost zero in soil at depths of 2.5 and 5 cm. However, Newell & Haramoto (1968) reported that total predation (mostly by ants) of larvae, pupae, and teneral adults of *D. dorsalis* was 36.3% in their field experiments.

In a recent study in Kula, Maui, Hawaii, Wong et al. (1984) found that the Argentine ant, *Iridomyrmex humilis* (Mayr) played a considerable role in reducing *C. capitata* populations in localized areas by as much as 38.8%. *I. humilis*, another species numerous in the Hawaiian Islands, was not found in the experimental field in Waimanalo because they have not yet invaded the area or because of some other ecological reasons. The averaged daily temperature minima and maxima in the Kula study was 13.2°C and 23.4°C, respectively. Monthly rainfall ranged from 0.1 cm to 8.4 cm and averaged 3.2 cm. *S. geminata* prefers a hotter, drier habitat than what may be suitable for *I. humilis*.

Other factors in addition to predation cause fly mortality. In the laboratory, over 95% of pupae produced adult flies in the absence of predators, while in the field only *C. capitata* 57.6% and 65.0% *D. dorsalis* emerged. Besides predators, the principal factors that might influence mortality in the soil appear to be micro-organisms, excessive moisture or dryness, or extremes of temperature. From the desiccated appearances of the pupae, mortality appears to have resulted either from heat or dehydration.

In the present study with *C. capitata* and *D. dorsalis*, field mortality of teneral adults by *S. geminata* was similar to that reported by Wong et al. (1984) for *C. capitata* and total mortality reported by Newell & Haramoto (1968) for *D. dorsalis*. We conclude that mortality of flies caused by foraging ants may play an important role in localized areas.

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REFERENCES CITED

Back, E.A. & C.E. Pemberton. 1918. The Mediterranean fruit fly in Hawaii. USDA Bull. 536. 118 pp.

Banks, W.A., C.S. Lofgren, D.P. Jouvenaz, C.E. Stringer, P.M. Bishop, D.F. Williams, D.P. Wojcik, & B.M. Glancy. 1981. Techniques for collecting, rearing, and handling imported fire ants. USDA Sci. and Ed. Admin. Adv. Agric. Tech. AAT-S-21: 1-9.

Bateman, M. A. 1976. Fruit flies, p. 11-48. *In* Studies in Biological Control. (V. L. Delucchi, Editor) Cambridge University Press. 297 pp.

Bishop, P.M., W.A. Banks, D.F. Williams, C.E. Stringer, J.A. Mitchell, & C.S. Lofgren. 1980. Simple nests for culturing imported fire ants. J. Georgia Entomol. Soc. 15: 300-304.

Chang, V.C.S. & A.K. Ota. 1976. Fire ant damage to polyethylene tubing used in drip irrigation systems. J. Econ. Entomol. 69: 447-450.

Huddleston, E.W. & S.S. Fluker. 1968. Distribution of ant species of Hawaii. Proc. Hawaii. Entomol. Soc. 20: 45-69.

Newell, I.M. & F.H. Haramoto. 1968. Biotic factors influencing populations of *Dacus dorsalis* in Hawaii. Proc. Hawaii. Entomol. Soc. 20: 81-139.

Pemberton, C.E. & H.F. Willard. 1918. A contribution to the biology of fruit-fly parasites in Hawaii. J. Agric. Res. 15: 419-465.

Pimentel, D. 1955. Relationship of ants to fly control in Puerto Rico. J. Econ. Entomol. 48: 28-30.

Wilson, E. O. 1962. Chemical communication among workers of the fire ant, *Solenopsis saevissima* (Fr. Smith). The organization of mass-foraging. Anim. Behav. 10: 134-147.

Wong, T.T.Y., D.O. McInnis, J.I. Nishimoto, A.K. Ota, & V.C.S. Chang. 1984. Predation of the Mediterranean fruit fly (Diptera: Tephritidae) by the Argentine ant (Hymenoptera: Formicidae) in Hawaii. J. Econ. Entomol. 77: 1454-1458.